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Assessing the inequalities in access to online delivery services and the way COVID-19 pandemic affects marginalization

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A B S T R A C T

This paper discusses the importance of incorporating online home delivery services (OHDS) into the concept of accessibility and marginalization. The authors propose a method to quantify access to OHDS and assess levels of inequalities in access to OHDS using data from OHDS providers in the pharmaceutical and food sectors, as well as from transport operators delivering parcels. The Västra Götaland Region in the West coast of Sweden is used as a case study. The results show significant inequalities in access to OHDS. Moreover, there are segments of population under a compound marginalization during the COVID-19 pandemic due to (i) limited accessibility to OHDS services, (ii) high incidence of COVID-19 cases in their area that makes physical visits to a store a risk activity, and (iii) high vulnerability (e.g., high share of individuals older than 65). These results reveal a need for the public sector to prioritize innovations in services that target specific clusters of the population that are vulnerable and marginalized, but also shows the imminent risk for some of these segments during the pandemic.

1. Introduction

Ensuring good access to food, shops, prescribed drugs, and other goods to members of a society is fundamental for quality of life and for economic development (Geurs, 2006). Enhancing accessibility is an important part of national transport plans and a key objective of transport policy. Although accessibility has traditionally focused on ensuring that people can travel to destinations that offer opportunities and supplies, the fast development of e-commerce calls for an additional dimension that focuses of accessibility to online home delivery services (OHDS). OHDS can provide access to goods for large parts of the population and equalize the relative level of accessibility between different social groups (Lucas et al., 2016). However, most research studies OHDS from a private sector perspective, and existing research on public policy focuses on environmental impacts rather than on their effects of accessibility or inclusiveness.

Innovations in, and hence the scope of, OHDS are traditionally driven by a business logic. If companies see an opportunity to increase sales by offering home delivery services and profit offsets the logistics costs, they will do it. This is highly determined by location and density (Hesse, 2002; Cárdenas et al., 2017). However, if companies cannot deliver or find a logistics service provider that can deliver the goods at profitable cost, they will not serve those areas. Although this logic is reasonable in a business environment, there are cases in which this ends up marginalizing some segments of the population that cannot get home deliveries of basic goods, such as medicine and food. As customer offerings of basic goods via online platforms has increased, accessibility and marginalization should not only be studied from a land use, and a transportation planning perspective but also from an access to OHDS perspective.

To further the understanding of transport accessibility, the concept of marginalization is introduced to the analysis. Marginalized segments of the population are defined here as populations that were not considered either when designing a service or end up be excluded due to the distinct features of the specific service, and are therefore treated as peripheral or not relevant. For OHDS, marginalization is a result of those services being designed and offered by private or mixed companies for profit and is caused mainly by location and by the lack of technical skills, e-literacy and access to cashless financial services of customers. Marginalization from OHDS has not been a pressing issue on transport policy as those marginalized segments can often get access to basic goods in physical stores even though this may imply higher cost and longer travel times.

Another key concept selected for the analysis of transport accessibility is vulnerability. Vulnerable populations are those that are more susceptible of being affected by crises and/or need special care related to

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socioeconomic factors such as, age, disabilities, income and integration to society. From a public policy perspective, stipulating equal access, it is important to identify vulnerable segments of the population that are being marginalized and design specific interventions to ensure access to services for those segments of the population.

Marginalization becomes a crucial issue that needs immediate governmental intervention when the service from which vulnerable segments of the population are marginalized is essential, such as deliveries of food. This has become more evident during the COVID-19 pandemic that has had a significant impact on the ability of delivery services to address new requirements on social distancing. Vulnerable citizens are asked to stay at their home as much as possible, which limits their ability to acquire goods from conventional retail channels. However, due to factors such as location, age, access to internet, internet literacy, availability of digital payment alternatives, they have also limited options in accessing basic goods via OHDS.

The purpose of this paper is twofold. The first one is to measure the level of access to basic goods via OHDS and compare it with demographics. This will allow to characterize segments of the population with different levels of access to OHDS to inform transport policy and allow prioritization of service design for marginalized and vulnerable segments. This paper also aims at assessing the level of OHDS access of population that live in areas with wide spread of COVID-19 cases, especially in areas with larger proportion of population vulnerable to COVID-19 (i.e., older individuals). This will inform policy makers and companies about areas where OHDS should be expanded to encourage physical distancing while ensuring access to basic goods.

Next section presents a literature review with focus on transport accessibility, online deliveries, and marginalization. Section 3 presents the case study and the data used in this study. Section 4 presents the method for data analysis. Section 5 presents the policy implications from this study and Section 6 offers some conclusions.

2. Literature review

As the topic of this research is at the intersection of different disciplines (transport policy, logistics, and information technology and digitalization), the literature review is structured around the review and integration of some basic concepts from these disciplines. To this end, the literature review is divided into three subsections: (1) Research conducted in relation to transport accessibility and its role in social equity; (2) the role and drivers of online deliveries and accessibility; (3) the marginalization resulting from lack of accessibility.

2.1. Transport accessibility and social equity

Although traditionally associated with mobility, transport accessibility stands for a broader meaning that covers movement, land-use, individual or group needs and time-based considerations (Brannigan et al., 2017). It can be defined as the opportunity of interaction (Hansen, 1959) available to an individual or a group at a given location to take part in a particular activity or reach a destination by a combination of transport modes (Gutiérrez and García-Palomares, 2020; Geurs and Van Wee, 2004). Alternatively, from a spatial perspective it refers to the capacity of a certain location to reach and to be reached from different locations in the transport system (Dalvi and Martin, 1976). Whilst the former definition concerns traveler's ability to reach a destination, called active accessibility, the latter focuses on the reachability of an activity or location by potential users, called passive accessibility (Cascetta et al., 2016). Addressing to different perspectives, these definitions lack the emphasis on the mobility of goods. As Geurs and Ritsema van Eck (Geurs and Ritsema van Eck, 2001) underline, accessibility is the extent to which transport system enables individuals, groups or goods to reach activities or destinations by utilizing transport system's tools and services.

Geurs and Van Wee (Geurs and Van Wee, 2004) have listed four components of accessibility: land-use, transportation, temporal and individual. Land-use component stands for the amount, quality and location of supplied opportunities such as jobs, schools, shops, etc. and the demand for these opportunities. Transportation refers to the disutility in time, cost and effort that an individual endures in getting to a destination from an origin. Temporal component is the time available for individuals for utilizing certain opportunities and time that those opportunities are available for use. Lastly, the individual component reflects the needs, abilities and opportunities of individuals which influence their access to transport modes.

The literature provides various system-based accessibility measures and indicators (Van Wee et al., 2001; Bocarejo et al., 2012). Infrastructure-based measures focus on the supply of transport infrastructure such as road networks, length of railways and sometimes combines these with the demand characteristics for transport. Activity-based measures relate to reachability of certain activities within given ranges of distances or number of populations. While it is common to use a mix of these two categories for measuring accessibility, another approach is assessing accessibility as an attribute of people (Weber and Kwan, 2003) which is focusing on the daily schedule of individuals and time available for reaching certain activities. In addition to these, a significant criterion for assessing accessibility is social equity or the extent to which certain activities are reachable by different social groups with different characteristics and needs. Such an approach is motivated by the transition from a system-based approach towards a people and needs-based approach to transport accessibility (Lucas, 2012).

The prevention of people from participating in economic, political and social life because of reduced accessibility to available social networks, facilities, goods and services due to poor transportation results in social exclusion in societies (Kenyon et al., 2002). Lucas (2012) explains inaccessibility and the resulting social exclusion as the intersection between transport disadvantage caused by lack of infrastructure, security, finances or information and social disadvantage caused by lack of education, health, income or jobs. This intersection is also called transport poverty which needs to be eliminated through achieving equitable transport accessibility.

Lack of equity is related to overlook of distribution effects or uneven distribution of access (Van Wee and Geurs, 2011). It is important how transport provision or land-use policies distribute accessibility opportunities among segments of the society with different social identities, levels of income, or various skill and ability levels (Guzman et al., 2017). The literature provides various equity principles to be incorporated into transport accessibility considerations ranging from horizontal, vertical, territorial equity to spatial or social equity (Thomopoulos et al., 2009). Among them horizontal equity refers to the accessibility approach where transportation resources are distributed evenly to groups and vertical equity implies that the same resources should be distributed in favor of disadvantaged social groups so that they have basic access to goods, services and other opportunities (Litman, 2002, 2017). Lucas, Van Wee (Lucas et al., 2016) combine egalitarian ethics with transport accessibility-based analysis to argue for such inclusive approaches to transport policy that consider vertical equity.

The definitions of accessibility address the inherent 'people' component within the concept and equitable accessibility emphasize this component even further with respect to needs and characteristics of different population segments. However, transport provision and land-use dimensions of accessibility call for a convergence of passenger transport and freight transport. Gonzalez-Feliu and Mercier (2013) underline a similar standpoint by referring to accessibility to goods by people and accessibility of goods to retail points. In addition, the rise of information and telecommunication technologies (ICT) introduced further implications of accessibility which requires expansion of transport system boundaries (Van Wee, 2013). Therefore, equitable transport accessibility needs to be discussed in relation to both personal and freight transport which are also being affected by ICT developments, particularly online shopping and consequences.

2.2. OHDS and accessibility

ICT developments followed by the rise in e-commerce have revolutionized the way goods are bought and delivered to consumers. Wide diffusion of e-commerce has driven significant changes in distribution channels and facilitated the emergence of new intermediaries (Allen et al., 2010). To keep up with the change in markets and maintain their competitiveness, the traditional, brick-and-mortar retailers are reorganizing and investing for building up omni-channel distribution capabilities (Mena et al., 2016), while pure click retailers are fighting for the market share. These developments in e-commerce have affected urban logistics significantly (Gonzalez-Feliu et al., 2014; Taniguchi et al., 2001) and facilitated urban logistics innovations focusing on green operations, new operators, and the use of new modes of vehicles (Dablanc et al., 2018). Both research and practice are focusing on how to improve OHDS, particularly in urban regions, in an efficient and innovative way (Lim et al., 2018). ICT-driven and sustainability-driven innovations are being introduced, applied, assessed constantly (Huschebeck and Leonardi, 2020).

Despite the extant research on OHDS and innovations in the last mile, focus on whom these innovations target is missing. From a consumer perspective, main functions of e-commerce are providing access to goods and services (Borenstein and Saloner, 2001; Rust and Lemon, 2001) at a lower price (Brown and Goolsbee, 2002), with greater variety (Brynjolfsson et al., 2003) and for a lower overall transportation cost (Keeling et al., 2007). On the other hand, from a provider perspective the last-mile delivery of e-commerce is regarded as the least efficient, most expensive leg of the distribution chain which is at the same time challenged by many external costs due to negative environmental impact (Gevaers et al., 2011). Therefore, providers are investing in OHDS innovations to improve efficiency and/or increase e-commerce sales so that the overall profitability of the business is enhanced. However, who benefits from these innovations is a neglected aspect.

Relating to the definition of transport accessibility which is the ability of reaching certain opportunities from a given location by using a certain transport system (Kitchin and Thrift, 2009), accessibility in an e-commerce setting is defined as *the ability of having access to goods from a given location by using available OHDS*. Similar with general urban settings (Behrends, 2016), high accessibility to their customers and meeting their needs at the lowest cost is the main interest for e-commerce retailers. However, if the cost of delivering is too high or the revenues in turn are too low for some customer segments, the lack of logistics service creates significant inequalities with respect to access to goods by consumers instead. This creates a gap as it is not the responsibility of the private sector to ensure access to OHDS, and transport policy does not include access to OHDS in their metrics of accessibility.

Improving accessibility to basic goods is a fundamental objective of achieving equitable transport accessibility (Van Wee and Geurs, 2011). Lack of equity in transport accessibility, besides other factors, is driven by the values, processes and actions of key delivery agencies which result in exclusion of certain societal segments (Lucas, 2012). In an e-commerce setting, with profit-driven values, it is likely that online delivery actors can prefer targeting profitable segments in expense of equitable accessibility to goods and services by disadvantaged segments of the population.

2.3. Marginalized populations due to lack of accessibility

Social exclusion refers to the prevention of participation to social life due to lack of accessibility to opportunities in a society that is built around the assumption of high mobility (Kenyon et al., 2002). This exclusion is a major consequence of transport deficiencies (Lucas, 2012). The inability to reach development opportunities results in economic and social outcomes such as lack of education, unemployment or poverty (Guzman et al., 2017; Grieco, 2015) and marginalization of these segments of populations (Church et al., 2000). categorize seven types of exclusion caused by transport poverty which are physical, geographical, economic, space, time-based, fear-based exclusion and exclusion from facilities.

On the other hand, e-commerce has been considered as central to improving access to goods and services by disadvantaged consumer segments due to geography, lack of transportation opportunities, high costs of conventional shopping and regional economic decline (Keeling et al., 2007). However, the statistics show that despite the steady increase in e-commerce sales (Worldwide, 2020), the appealed market segments by e-commerce are composed of young, active consumers with high social status and who are living in urban or sub-urban areas (E-shopping, 2020; Postnord, 2019; Roos et al., 2019). The situation indicates that vulnerable segments of the population (i.e., the elderly, the people from less advantaged parts of society or people who are geographically segregated) are marginalized by lack of access to e-commerce markets. Furthermore, ICT-based innovations in online deliveries that demand enhanced consumer capabilities exacerbate the situation as lack of ICT skills cause e-exclusion risks for low-income, low education, older age, rurally located, long-term unemployed, disabled, or minority population segments (Keeling et al., 2007). When these consumers enter service exchange in e-commerce markets with their existing disadvantages, their lack of ICT skills might result in discriminatory actions by service providers (Rosenbaum et al., 2017). This problem is often referred in the literature as digital divide (Morris, 2007), which hampers accessibility to emerging online home delivery services. One marginalization factor that is less discussed but has revealed itself as an important factor for online shopping during the pandemic is the lack of access to digital payment methods (se, 2020). In some cases, this is a consequence of not having asocial security number for immigration reasons which hinders banking access.

As noted by Grieco (2015), transport accessibility and affordability are important dimensions of social sustainability where they need to be considered not only from a user perspective but also the provider perspective. However, in an e-commerce context, affordability from a provider perspective can reduce the availability of online delivery services which, in turn, hampers accessibility to goods by the mentioned marginalized segments of the population. The pandemic has caused an expansion of these segments due to restrictions imposed on risk groups or people who are sick. As a result, a surge in e-commerce volumes has been observed in certain product categories such as food, groceries and personal hygiene which were accompanied with a surge in online delivery services. Who has access to these services, particularly among the marginalized population segments, is a question yet to be answered.

Conclusively, this study seeks to respond to calls for further understanding of accessibility of OHDS, with specific focus on inequalities and the impact of Covid-19 that can lead to a whole new type of risk, namely further marginalization of some consumer segments. In particular, the study seeks to address the following research and knowledge gaps:

- *Context: OHDS* offers a firm perspective of *consumers, or end-users*, in a setting that has grown fast with respect to importance during Covid-19 (e.g. safety protection and contactless modes of delivery).
- *Factors:* Much attention has been given to the up-stream implications of *Covid-19*, i.e. impact on materials flows of transport providers, manufactures, and retailers. This study offers a firm view on not only consumers as a new actor but seeks to include those who risk to fall beyond the traditional boundaries of OHDS.
- *Relationships:* The immediate response to Covid-19 in OHDS follows somewhat the conventional factors in urban distribution innovation, namely urban planning and new technological and organizational modes of moving and storing goods. By taking a stance at the consumer end, the study provides an opportunity for complementing the predominated view on sustainability from an environmental point of view with a *social* dimension. More specifically, the study reveals that OHDS may *potentially fall into unstainable practices.*

- *Raise a fundamental question:* Traditionally, accessibility is defined in terms of terms of the ability or activities of the transport system (e.g. reach in distance), rather than considering the ability of consumers to engage in or become part of OHDS. In line with social responsibility, taking the marginalized approach complements the emerging needs-based approach in urban freight transport by encouraging a *fundamental re-definition of the consumer's* role and engagement in the transport system towards an *active accessibility*. By this, the risk concept is also extended from concerning accessibility in terms of reach but also a new category of risk, namely the one of OHDS excluding parts of the consumer segments.

3. Case study, data collection and method

This section is divided in two sub-sections. The first sub-section presents the case study selected for this research and the second sub-section presents the data that were collected in the study area.

3.1. Case study

The region of Västra Götaland in the West Coast of Sweden was selected as a case study. The Västra Götaland Region (VGR) is one of the 21 counties of Sweden, the county is further divided into 49 municipalities. The VGR is a politically controlled organization that ensures access to healthcare and works with culture, public transport economic growth and a strong emphasis in sustainable development. VGR develops its plan and strategy in collaboration with municipalities, business organizations, associations and other actors. The Region is seen as Scandinavia's leading logistics hub—partly as a consequence of being home to the Port of Gothenburg—and as a leader in innovative initiatives (John WedelCLuster Analysis Logistics, 2020).

In line with the purpose of this research, the authors decided to collect data to assess (i) access to OHDS based on data from companies, (ii) demographics in a specific area measuring attributes, such as, age, income, or education based on demographics data, and (iii) the number of COVID-19 cases based on VGR statistics for the pandemic as a proxy of exposure to the disease on shared environments. The geographical unit selected for the analysis for OHDS and for demographics was the postcode because data could be found and analyzed without disclosing personal information, while for COVID-19 cases the data could only be obtained at the municipality level.

There are 1793 postcodes and 49 municipalities in the VGR. The postcodes' average population is 963 inhabitants with a range from 0 to 3457 (there are 106 postcodes with less than 100 inhabitants). Given the large number of postcodes and the significant data collection effort that each observation some sampling is necessary. It is noteworthy that OHDS data were in most cases obtained manually as requests to companies were denied due to confidentiality concerns. For the sample, a 30% of the postcodes from VGR were randomly selected. As shown in Table 2, the population in the postcodes sampled cover 503,583 inhabitants, the distribution of this population across age brackets, education level and citizenship is almost identical to the one in the VGR (see Table 1).

3.2. Data description

The type of goods selected for the study were parcel, prescribed drugs, and food. The companies sampled to collect data about OHDS were based on their market share.

For parcel deliveries, three companies were selected: Company#1 in charge of the national post delivery service which is mandated by law to deliver letters but not parcels to every person in Sweden (and this could be through a delivery point at a significant distance from house units), Company#2 which is an express parcel service, and Company#3 which is a third-party logistics service that serves both B2C and B2B flows with parcel and large boxes and makes home deliveries.

For prescribed drugs, two pharmacies were selected. Those pharmacies were the first ones in offering home deliveries for prescription medications in Sweden and they also have the largest market share. These pharmacies do not provide delivery service themselves but through third-party logistics service providers. Before COVID-19 pandemic they did not offer deliveries to all postcodes in the VGR, but at the time of collecting the data (Spring 2020) they deliver to all postcodes either via pick-up points or home deliveries. One of the pharmacies has two transport providers, the national post delivery service which delivers mainly through pick-up points and a third-party logistics operator which does home deliveries for a 39SEK fee (i.e., ≈3.8 EURO). The other pharmacy has a wider range of transport providers and all deliveries are free of charge.

For food, two companies offering home deliveries of groceries and a company offering meal deliveries from restaurants were selected to cover the two main type of food deliveries. All companies were contacted to obtain the information, in some cases the information was provided by the companies but in most cases the data was compiled from publicly available websites. The names of the companies are not mentioned as they considered this was sensitive information.

A second database containing demographic information for each postcode was obtained from Sweden Statistics. This database provides information about number of inhabitants, age, level of education, and income by postcode which covers most of the factors, according to Keeling, Macaulay (Keeling et al., 2007), that can generate exclusion and can be classified as vulnerable. This database is used to contrast access to delivery services and demographic characteristics of the population in each postcode.

A third database was obtained from VGR that tabulates the number of cases for each municipality in the region.

The data used for analysis in this paper was collected during the first wave of the pandemic (Spring 2020), the authors conducted a new data collection during the third wave of the pandemic (April 2021) when the paper was already in the middle of the review process. The results are presented in the conclusion as a motivation for further research. The new data collection provides a glance on how the pandemic has changed accessibility via OHDS, but a thorough post-pandemic study is necessary to continue assessing the effects of the pandemic.

3.3. Method

Based on the literature review it is possible to identify some key factors that lead to marginalization from OHDS. These factors are (i) low

Table 1
Breakdown of Västra Götaland population by age, education and citizenship.

Age vs Citizenship & education	Swedish		European (EU28)		Other		Total
	Basic education	Advanced education	Basic education	Advanced education	Basic education	Advanced education	
0–24	453,195		10,336		34,687		498,218
25–44	198,767	198,539	6083	11,564	19,824	19,606	454,383
45–64	239,836	155,218	6334	5113	7069	3801	417,371
>65	237,932	84,924	5859	1544	902	445	331,606
Total	1,568,411		46,833		86,334		1,701,578

Table 2
Breakdown of sampled population by age, education and citizenship.

Age vs citizenship & education	Swedish		European (EU28)		Other		Total
	Basic education	Advanced education	Basic education	Advanced education	Basic education	Advanced education	
0–24	132,664		3061		10,795		146,520
25–44	59,022	58,753	1801	3418	6188	6275	135,457
45–64	70,633	45,033	1906	1475	2251	1206	122,504
>65	71,391	25,081	1781	435	277	137	99,102
Total	462,577		13,877		27,129		503,583

access to OHDS due to location, (ii) low income, and (iii) digital literacy: poor e-literacy, technical skills, and lower integration to digital payment services. Access to OHDS can be measured and income data is available in demographic datasets. Although e-literacy, technical skills and availability of digital payment services are more difficult to assess, other variables such as advanced age, low education and citizenship can be used as proxies to explain the digital divide according to (Morris, 2007).

The following sub-sections explain the method to assess access to OHDS, to identify clusters of population according to relevant socio-economic characteristics, and to assess their risk of exposure to COVID-19 and vulnerability.

3.3.1. Assessment of the levels of access to OHDS

The operationalization of the accessibility concept relies on the definition of *service attributes, access indicators,* and *accessibility indices* which measure accessibility as a variation from the infrastructure-related approaches to measure overall transport accessibility (Van Wee et al., 2001). Instead of measuring travel times for end users, this research focuses on how extended each OHDS company's service network is in each postcode, distance to pick-up points and whether home delivery is available. The definition of *service attributes* was constrained by the type of data publicly available.

The three types of measures selected to assess access to OHDS were: (i) *service attributes* (x) that were collected to assess access for each company studied and each postcode, (ii) *indicators* (I) were then calculated to measure access for each type of goods and postcode, and (iii) *indices* (D) were calculated to assess the overall OHDS access of a cluster relative to others cluster in the study area.

For parcel delivery companies, as those companies often deliver to pick-up points (e.g., a local store or a supermarket) the *service attribute* selected was the inverse of distance to the closest pick-up point for Company#1, the number of delivery points within 2 km from the centroid of the postcode for Company#2, and whether home delivery is available for Company#3. For prescribed drugs, the *service attribute* selected was whether a postcode is served via pick-up points or if home delivery is available (attribute value 0 and 1, respectively). For food, the *service attribute* was whether a postcode is served or not by the service, with attribute value 0 or 1 respectively.

After collecting data for each *service attribute*, an *indicator* was derived to capture access to OHDS. Thus, the *indicator* for each type of goods is calculated as a weighted average value of the *service attributes* for the different companies serving that type of goods in each postcode. As the *service attributes* (j) can have different definition for different types of goods, the value of the *indicator* is not comparable across types of goods. The following equation (1) was used to calculate an *indicator* (I) for each type of good (i) and postcode:

$$I_i = \sum_j \left(w_{i,j} * x_{i,j} / max\left(x_{i,j}\right)\right) \Big/ \sum_j \left(w_{i,j}\right) \tag{1}$$

Where, $x_{i,j}$ denotes the value of *service attribute j* for type of good i, and $w_{i,j}$ refer to the respective weight depending on the importance of *attribute j* for type of good i. For parcels, the weights were 1 for the normalized inverse distance to the closest delivery point for Company#1, 1 for the normalized number of delivery points within 2 kms for Company#2, and 2 for home deliveries from Company#3. For pharmacies, the service attribute being the same both companies were given the same weight. For food, companies doing grocery deliveries to home were given a weight of 2, while meal deliveries from restaurants were given a weight of 1. The weights were chosen by the authors based on discussions with different OHDS users.

The method implemented to identify different levels of access to OHDS is the K-means algorithm. The application of K-means allows to partition postcodes in a way that minimizes within cluster variance for the indicators defined in the previous section as in eq. (2):

$$min_S \sum_{k=1}^{K} \sum_{\boldsymbol{x} \in S_k} \boldsymbol{x} - \boldsymbol{\mu}_k{}^2 \tag{2}$$

Where K is the number of postcodes, $\boldsymbol{x}$ is a vector denoting OHDS *attributes* for each of those postcodes, and $\boldsymbol{\mu}_k$ is the mean of all *service attributes* for the postcodes belonging to cluster S_k. It is noteworthy that *service attributes* were used for partition rather than *indicators* as they allow more detail when characterizing OHDS access (e.g., postcodes with low access to restaurant deliveries but good access to grocery deliveries). Equation (2) allows the partition of postcodes among n number of clusters. The algorithm is then applied multiple times for $n = 1$ to $n = 10$ and the cubic clustering criterion is calculated (nstitute Inc.P(R, 2018). The optimal number of clusters is selected based on the highest cubic clustering criterion. However, it is important to consider other aspects, such as, the practicality of the number of clusters, the number of observations within a cluster and the conceptual validity of the clustering.

Once the clusters are determined, it is possible to derive an *index* (D) for each cluster (i.e., a composite measure of access to OHDS relative to the other clusters). This allows to compare accessibility to OHDS across clusters. The *index* D_{S_k} compares the coverage of each cluster S_k to the coverage of the best covered cluster using the following expression:

$$D_{S_k} = \sum_i \left(w_i * I_i^{Sk}\right) \Big/ max\left(\sum_i \left(w_i * I_i^{Sk}\right)\right) \tag{3}$$

Where I_i^{Sk} is the mean value of the indicator of type of goods i for all postcodes belonging to cluster S_k, w_i is the weight for each type of goods indicator. Based on discussions with users, coverage of prescribed drugs and food were given a weight of 2 while parcels a weight of 1.

It is noteworthy that the clusters are created based on access data and instead of on services attributes to ensure that subjective measures such as weights do not affect the clustering process. The calculation of indicators and indices are done after the clusters are created and the purpose is to compare clusters by service attributes via a common metric. Weights can be changed by decision-makers depending on their preferences.

3.3.2. Identification of demographics clusters in the VGR

A similar method was implemented to group and classify postcodes according to demographics using clustering. In the case of demographics, there is a hierarchy in the data, thus a hierarchical clustering was implemented. Ward's method is used to cluster the postcodes by minimizing information loss when two clusters are joined (Klimberg and McCullough, 2016). This method calculates iteratively the sum of squares within clusters as in equation (2) and selects the partition that minimizes it for a specific number of clusters.

The main difference between the K-mean algorithm implemented for levels of access to OHDS and the hierarchical clustering applied for demographics is that K-means uses a random start while hierarchical clustering starts with a single cluster and divides it sequentially. The number of clusters is selected using a conceptual validity criterion supported by the "elbow" method in the scree plot for the sum of squares (Klimberg and McCullough, 2016).

3.3.3. Risk of exposure to COVID-19 and vulnerability

As mentioned in the problem statement, one of the objectives of this research is to identify segments currently marginalized from OHDS and segments of population that are vulnerable and at risk of being infected with COVID-19. After several contacts with the VGR division in charge of data analytics related to the pandemic, the best data available to identify population vulnerable and at higher risk was based on age and the number of cases in the geographic area. It is noteworthy that data related to health conditions that make the population more vulnerable to COVID-19 could not be shared by VGR. Another characteristic that was shown to increase vulnerability and risk of death is having a non-European background as language barrier and access to information hinder the government efforts to prevent and treat the disease (Sverigesradio, 2020). As origin or background was not available, citizenship has been used as a variable to capture this type of vulnerability.

4. Results

4.1. Cluster analysis and OHDS access index

For the overall sample, the OHDS access *indicators* were scaled to range between 0 and 1, with a mean value of 0.08 for parcels, 0.40 for prescribed drugs and 0.39 for food. In terms of each company's *attributes* the values are as follows. For parcels the distance to pick-up points for Company#1 ranges between 0.012km and 23km with a mean distance of 3.00km; the number of pick-up points within 2km for Company#2 ranges between 0 and 15 with a mean of 2.5; and for Company#3 8.9% of postcodes are covered with home delivery. For prescribed drugs, 18.5% and 61.6% of postcodes are covered with home delivery by Pharmacy#1 and Pharmacy#2, respectively. For food, 45.3% and 47.4% of postcodes are covered with grocery deliveries by each e-grocer studied. Meal home deliveries are available for only 6.9% of the postcodes.

The application of the cubic clustering criterion in the K-means algorithm allowed to identify nine clusters within the postcodes codes. The description of each cluster's characteristics in terms of *indicators* for each type of good and the *index* for relative coverage for each cluster is presented in Table 3. As described in Section 3, the indicators provide an absolute measure of access to OHDS while the indices provide a measure of access to OHDS relative to other clusters.

Table 3
Description of clusters of OHDS access characteristics.

Cluster	Obs.	Overall coverage index	Parcels indicator	Prescribed drugs indicator	Food indicator
I	19	High (D = 1.00)	High (I = 0.71)	High (I = 1.00)	High (I = 1.00)
II	16	High (D = 0.92)	High (I = 0.71)	High (I = 1.00)	High (I = 0.80)
III	16	High (D = 0.80)	Low (I = 0.10)	High (I = 0.84)	High (I = 1.00)
IV	47	Medium (D = 0.76)	Low (I = 0.08)	High (I = 1.00)	Medium (I = 0.75)
V	126	Medium (D = 0.55)	Low (I = 0.04)	Medium (I = 0.49)	High (I = 0.78)
VI	108	Low (D = 0.21)	Low (I = 0.03)	Medium (I = 0.43)	Low (I = 0.05)
VII	23	Low (D = 0.18)	Low (I = 0.01)	Low (I = 0.02)	Medium (I = 0.40)
VIII	56	Low (D = 0.00)	Low (I = 0.02)	Low (I = 0.00)	Low (I = 0.00)
IX	97	Low (D = 0.00)	Low (I = 0.00)	Low (I = 0.00)	Low (I = 0.00)

As shown, clusters I to III have a good coverage overall. Cluster IV and V have medium coverage overall. Clusters VI and VII have medium to low coverage with differences across type of goods: Cluster VI has medium access to prescribed drugs OHDS but very low access to food OHDS, and Cluster VII has medium access to food OHDS but very low access to prescribed drugs OHDS. Clusters VIII and IX have very low access to OHDS. It is noteworthy that 10% of postcodes belong to clusters having good OHDS access, 34% of postcodes belong to clusters having medium to low access, and the other 55% of postcodes belong to clusters with low to very low access.

Fig. 1 shows the OHDS clusters in the metropolitan area and in the VGR. The colors in the maps indicate the *index* for each postcode and the label shows the cluster number. As expected, there is an evident divide of access to OHDS based on proximity to Gothenburg, postcodes in the Gothenburg metropolitan area tend to be in clusters I, II and II, but there are also some postcodes in the metropolitan area belonging to clusters IV and V, and a few postcodes belonging to clusters VI and IX in the outer zone of the metropolitan area. The map of the VGR shows a dominance of postcodes in clusters VI and IX in the postcodes that are farther from Gothenburg.

4.2. Classification of postcodes by socio-economic characteristics

Using hierarchical clustering and based on the "elbow" method as well as on the conceptual validity of the clusters the authors identified six clusters within the postcodes studied. The dendrogram and constellation plot illustrating the partitioning of postcodes between clusters are shown in Fig. 2.

The dendrogram and the constellation plot provide an illustration of the segmentation based on similarities across variables, but the statistical criterion was not the only one considered when selecting the most suitable clustering. In order to have a segmentation of the population into groups, it is necessary to identify groups that can be described based on the shared characteristics. This was done by analyzing the socio-economic variables and the difference in those variables across clusters. The description of each cluster's characteristics is presented in Table 4.

As shown in Table 4, each cluster can be characterized based on the socio-economic attributes. For instance, Cluster I groups postcodes with large population, a low share of Swedish citizens, high share of non-Swedish non-European citizens, low income and a large share of young people. Clusters IV, V, and VI have a medium to large share of population older than 65, all with medium to high share of Swedish citizens, Clusters VI has low income and medium share of non-Swedish non-European citizens. Cluster IV has higher education level than clusters V and VI. Based on the literature review, the attributes found in clusters IV, V and more manifestly in Cluster VI are more vulnerable and are at risk of being marginalized from basic services.

As shown in Fig. 3, most postcodes belonging to demographic clusters I, II and III are located in the metropolitan area of Gothenburg, while most postcodes in demographic clusters IV and V are mainly located farther away from Gothenburg. Cluster VI is an interesting case with postcodes both in the metropolitan area of Gothenburg and in the external part of the VGR. Fig. 4 shows the number of COVID-19 cases for each postcode in the sample to illustrate the different levels of risk of getting sick.

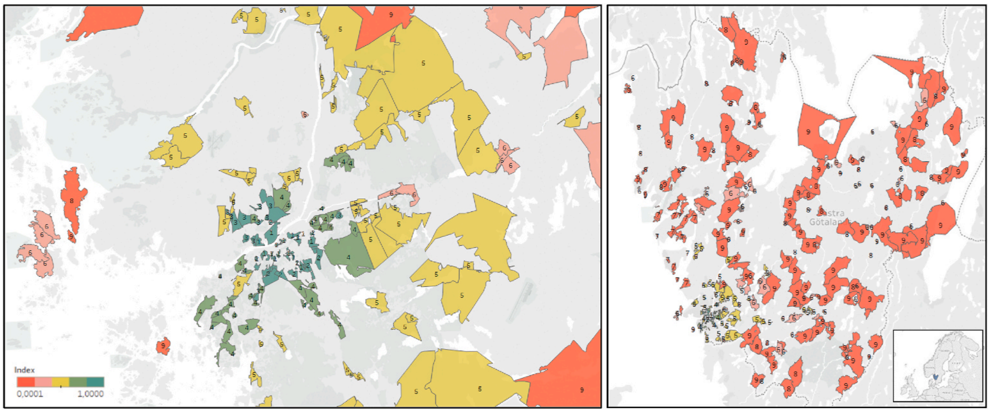

Fig. 1. OHDS clusters in the metropolitan area of Gothenburg (left), and overall in the VGR (right).

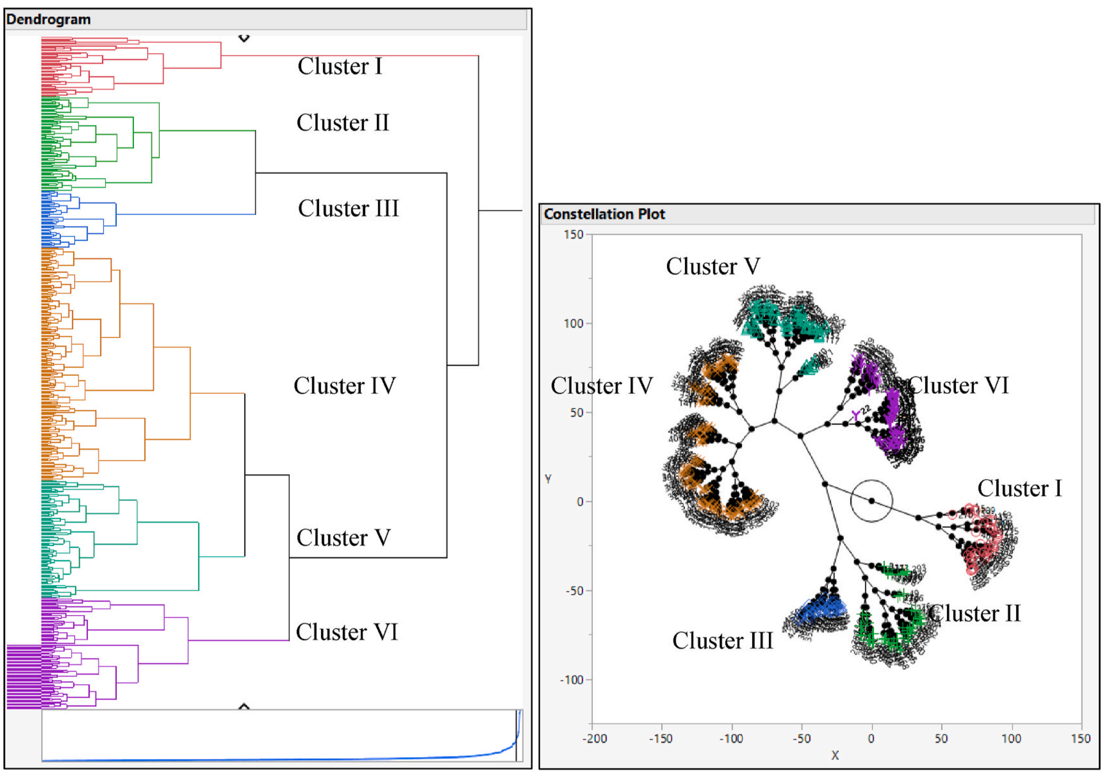

Fig. 2. Dendrogram and constellation plot using demographics.
Notes: Income corresponds to yearly income in Swedish Crowns. For the classification as low, medium, high the data is normalized using =(value-min(clusters))/(max(clusters)-min(clusters)), and then all indices lower than 0.25 are classified as low, 0.25–0.75 are classified as medium, and 0.75–1.00 are classified as high.

4.3. Classification of postcodes by risk of exposure to COVID-19

The number of cases per municipality is shown in Fig. 1, cases range between 22 and 192 per 10,000 inhabitants and an average of 393 cases per municipality. The main city, Gothenburg, which concentrates one third of VGR's population has the most cases with 6722 and one of the highest number of cases per 10,000 inhabitants (116). The data show cases until July 12, 2020.

The data on COVID-19 cases for each municipality within the VGR is shown in the Appendix. The postcodes within each of these municipalities were identified to allow for a comparison with the OHDS and socio-economic data. Each postcode was classified as low risk of exposure (<50 cases/10,000 inhabitants), medium-low risk (between 51 and 100 cases/10,000 inhabitants), medium-high risk (between 101 and 150 cases/10,000 inhabitants) and high risk (>150 cases/10,000 inhabitants).

4.4. Comparison between OHDS, demographics and exposure to COVID-19

The postcodes were tabulated to assess the number of postcodes within each combination of demographic, OHDS access clusters, and incidence of COVID-19 cases. Cramer's V tests were used to assess relationships between the belonging to different clusters. The chi2, Cramer's V and probability values are reported to support the analysis.

As shown in Table 5 and with the chi2 test and Cramer's V test there is a strong statistically significant association between demographic and OHDS access clusters. The combination with the largest share of postcodes is Demographic Cluster IV (i.e., high share of Swedish citizens, medium income, and medium share of old population >65) and OHDS

Table 4
Demographic clusters and characteristics.

Obs.		Cluster					
		I	II	III	IV	V	VI
		45	71	43	176	89	84
Population	Mean	1456	1304	1199	1035	495	900
	Level	*High*	*High*	*Medium*	*Medium*	*Low*	*Medium*
Swedish citizens	Share	75%	91%	96%	95%	95%	87%
	Level	*Low*	*High*	*High*	*High*	*High*	*Medium*
European citizens	Share	5%	3%	2%	2%	3%	4%
	Level	*High*	*Medium*	*Low*	*Low*	*Medium*	*Medium*
Other citizens	Share	18%	5%	1%	2%	1%	8%
	Level	*High*	*Low*	*Low*	*Low*	*Low*	*Medium*
Advanced education	Share	36%	58%	60%	35%	28%	27%
	Level	*Medium*	*High*	*High*	*Medium*	*Low*	*Low*
Income	Mean	196,141 kr	339,178 kr	405,137 kr	314,960 kr	291,842 kr	255,624 kr
	Level	*Low*	*Medium*	*High*	*Medium*	*Medium*	*Low*
Age: 25–44	Share	35%	38%	21%	24%	19%	25%
	Level	*High*	*High*	*Low*	*Medium*	*Low*	*Medium*
Age: 45–65	Share	18%	22%	27%	26%	30%	22%
	Level	*Low*	*Medium*	*High*	*Medium*	*High*	*Medium*
Age: >65	Share	11%	15%	18%	22%	28%	24%
	Level	*Low*	*Low*	*Medium*	*Medium*	*High*	*High*

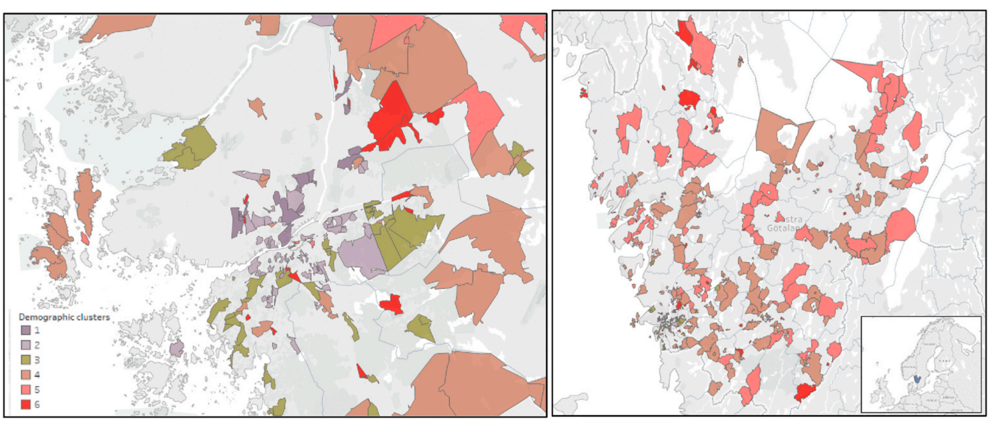

Fig. 3. Demographic clusters in the metropolitan area of Gothenburg (left), and overall in the VGR (right).

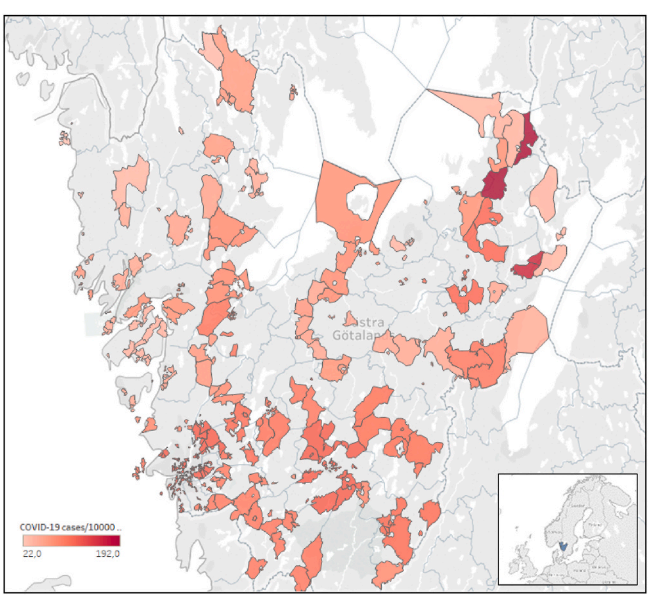

Fig. 4. Number of COVID-19 cases per 10,000 inhabitants for municipalities in the VGR.

Access Cluster VI (i.e., low overall access with very low access to food) which contains 60 postcodes or 12% of all postcodes. It is interesting to note that all OHDS clusters with low access (clusters VII to IX) correspond to demographic clusters IV, V and VI (all of them with medium to high share of older population, medium to low income, and medium to low population).

Table 6 shows the tabulation of risk of exposure to COVID-19 and vulnerability versus the different types of clusters.

As confirmed with the chi2 and the Cramers'V test, there is a strong and statistically significant correspondence between cases per 10,000 inhabitants and both the demographic clusters and the HDS access clusters. The Cramer's V tests also show that this association is stronger for the OHDS clusters than for demographic clusters. Overall, there are 69 postcodes (13% of postcodes studied) that belong to clusters that are classified as vulnerable according to their demographics, that have medium-low to low access to OHDS and that are in areas with medium-high to high risk of exposure to COVID-19. There are 54,500 persons living in those postcodes, from which 12,233 are older than 65. The location of the postcodes is shown in Fig. 5. As shown, they are distributed across the VGR, only 10 of those are in Gothenburg's Metropolitan Area.

5. Discussion and policy implications

The implementation of the method proposed to the VGR case study

Table 5
Number of postcodes within each Demographic and OHDS access clusters.

Number of postcodes		Demographic clusters						*Total*
		I	*II*	*III*	*IV*	*V*	*VI*	
OHDS access clusters	*I*	2	14	1	-	2	-	19
	II	1	12	2	-	-	1	16
	III	5	9	-	1	-	1	16
	IV	5	22	11	8	-	1	47
	V	26	11	23	41	2	23	126
	VI	6	2	5	60	9	26	108
	VII	-	-	-	8	13	2	23
	VIII	-	-	-	20	14	22	56
	IX	-	1	1	38	49	8	97
Total		45	71	43	176	89	84	508

Note: Pearson chi2(40)=465.57, Pr =0.000, Cramer's V=0.428

Table 6
Clusters versus risk of exposure to COVID-19.

Number of postcodes		Risk of exposure to COVID-19				Total
		Low	Medium-Low	Medium-High	High	
OHDS access clusters	*I*	-	-	18	-	18
	II	-	-	16	-	16
	III	-	-	15	-	15
	IV	-	7	40	-	47
	V	-	41	85	-	126
	VI	9	56	**35**	**2**	102
	VII	19	4	**-**	**-**	23
	VIII	22	24	**6**	**2**	54
	IX	22	45	**25**	**4**	96
Total		72	177	240	8	497

Note: Pearson chi2(24)=279.18 Pr =0.000, Cramer's V=0.433

Number of postcodes		Risk of exposure to COVID-19				Total
		Low	Medium-Low	Medium-High	High	
Demographic clusters	*I*	2	3	40	-	45
	II	-	6	63	-	69
	III	-	12	31	-	43
	IV	22	86	**61**	**2**	171
	V	31	34	**21**	**3**	89
	VI	17	36	**24**	**3**	80
Total		72	177	240	8	497

Note: Pearson chi2(15)=161.44 Pr =0.000, Cramer's V=0.329

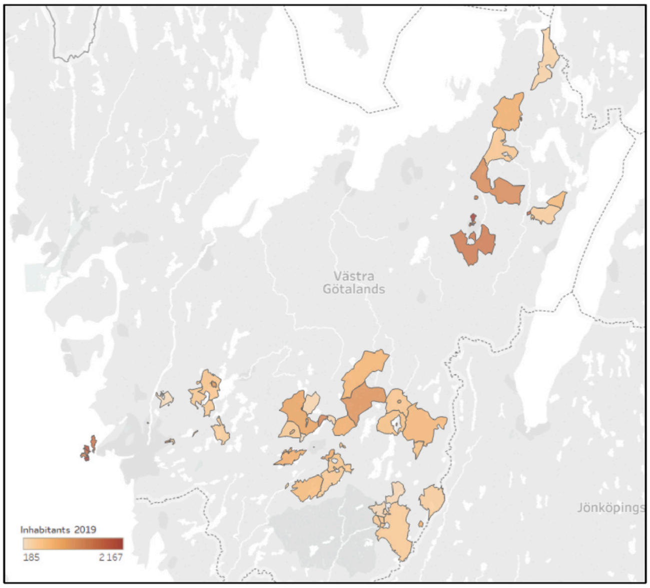

Fig. 5. Postcodes classified as vulnerable, at risk of exposure to COVID-19 and low access to OHDS.

and the analysis reveal a significant variation in the access to OHDS across postcodes in the first wave of the pandemic. Access to OHDS of prescribed drugs (40%) is less extended than access to groceries OHDS (46%). As expected, Gothenburg's metropolitan area has better access to OHDS but not all postcodes in that area have full coverage.

The comparison of OHDS access and demographics revealed an interesting but concerning result. There is a statistically strong relationship between low access to OHDS and population that tend to be excluded from other opportunities (Keeling et al., 2007) and are more vulnerable (i.e., older population, lower income, lower level of education). These results show that there is a need for a public sector intervention to increase access to OHDS in those areas rather than maintain a *laissez faire* approach. Public authorities need to consider vertical equity (Litman, 2002, 2017) and encourage or subsidize service providers to improve accessibility of OHDS by disadvantaged, vulnerable segments of the population. Although, in this case, one of the sample companies had a public mandate to provide delivery service to all members of the population, the results indicate that the coverage of the service was not inclusive enough during the first wave of the pandemic. Therefore, closer control by policy makers or clearer service requirements could improve inclusivity of OHDS during the pandemic and undertake necessary measure to maintain high levels of accessibility after the pandemic.

Another policy implication could be to trigger complementary intervention by public authorities in the form of (i) a public OHDS service that covers neglected regions with an inclusive approach to certain segments of the population with low accessibility due to either location, demographic characteristics, or vulnerability, (ii) investments in the public postal company (60% owned by Swedish state) to cover more locations with OHDS, and (iii) update and expand current directives so that the State owned postal service company should ensure access not only to letters but also to parcels and create guidelines on what are acceptable levels of accessibility. It is noteworthy that this would not be a direct competition with private service providers but a complementary one which could in the future lead to market development focusing on social equity and accessibility. It is also likely that the higher penetration of e-commerce and OHDS in currently marginalized areas will lead to economies of density that will make home deliveries economically attractive for logistics companies.

Moreover, the comparison with COVID-19 cases showed that there is an important share of population (i.e, about 10% of the population studied and 12% of population >65) that live in postcodes with medium-high to high number of cases per 10,000 inhabitants, and that have medium-low to low access to OHDS. This reveals a pressing need to increase OHDS coverage in those areas which can lead to lower spread of COVID-19 and less deaths. As described in a companion paper (Altuntas-Vural et al., 2020), companies providing online delivery services during the pandemic have identified this problem and have reacted by implementing initiatives to ease access to OHDS without requiring advanced IT skills, eliminating the need for a social security number for registration, adopting new payment methods, and extending the geographical reach of their services among others. While social organizations have reacted to alleviate the consequence of the lack of access to OHDS by organizing and young people providing delivery services in their neighborhoods (se, 2020), an intervention from the public sector should capitalize on efforts already been undertaken by the private sector and social organizations. Policy measures that introduce new functions to already existing public services could be one solution. For example, the home care services that are run by municipalities in Sweden can be organized in a manner where collaboration is made with these voluntary initiatives or where these initiatives are embedded into existing home care services. This would extend the coverage of home care services and combine it with OHDS for vulnerable and excluded population segments.

It is crucial to recognize the importance of OHDS in ensuring access to goods and diminishing marginalization, as well as measuring this access and identified segments of the population that need to be prioritized both in a normal time and in the middle of a pandemic. The method developed in this study introduces new measures for policy makers who exclude OHDS from their transport accessibility metrics. An important policy implication is to adopt and develop such measures further to include mobility of goods into previously defined accessibility metrics and rethink accessibility strategies accordingly.

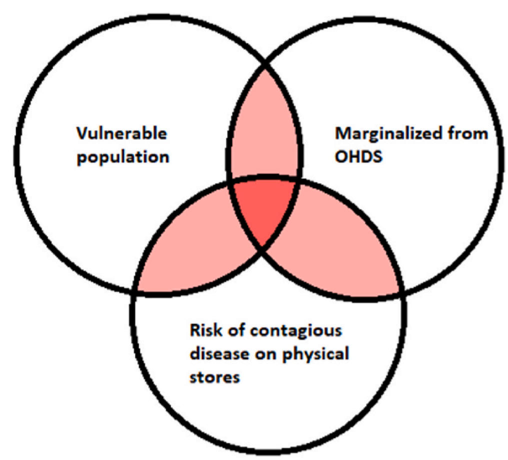

Fig. 6. Venn diagram showing overlaps of population segments in terms of marginalization from OHDS, vulnerability and risk of contagious disease.

Fig. 6 illustrates how marginalization from OHDS of vulnerable segments of the population can be compounded by a risk of being infected by COVID-19.

As shown in the Venn diagram in Fig. 6, some segments of the population can be classified as vulnerable population, others as marginalized from OHDS, and others as at risk of contagious disease on physical stores. Population that are vulnerable and marginalized from OHDS require some attention from the public sector (e.g., retirement homes, special transport services), population that are vulnerable and at risk from contagious disease can get access to basic goods via OHDS, and population that are marginalized from OHDS and at risk of contagious disease can often still go to physical stores using precautions as the risk of getting seriously ill is lower. The main issue are the segments of the population in the inner part of the diagram that are vulnerable, live in areas of high risk of contagious disease and are marginalized from OHDS. Those require urgent attention.

6. Conclusions

This paper has integrated socially equitable transport accessibility literature with OHDS in order to address the fundamental service design gap of OHDS that results in exclusion of certain populations. The study shows how this exclusion was exacerbated with Covid-19 pandemic where more parts of the population became marginalized due to geographical, demographic and health-related reasons. Previous research has focused on the digital divide, how it affects access to information, goods, adoption of technology or e-commerce. Departing from the digital divide, this study introduces a new concept: *the logistics divide which is defined as the lack of equitable accessibility to OHDS*. The results provide evidence for reduced accessibility to OHDS by certain segments of the population and indicate that these segments are significantly characterized by disadvantaged demographics and a high Covid-19 infection rate.

The study contributes to transport accessibility literature, which is primarily concerned with passenger mobility, by extending it with freight transport and introducing mobility of goods into the accessibility definition. By emphasizing the accessibility to OHDS by different segments of the population, the study extends (Cascetta et al., 2016) passive accessibility concept to e-commerce setting for basic goods. Furthermore, the study contributes to transport policy literature by highlighting the importance of accessibility to OHDS by disadvantaged and vulnerable segments of the population during a time when mobility and physical presence was discouraged.

It is important to note that although the impact of marginalization from OHDS has been compounded by the pandemic, the societal costs of this marginalization is not limited to the risks related to the pandemic. Contrary, it is crucial to learn from the practices and policy that have been implemented during the pandemic to create a sustainable transportation system that includes social responsibility, and in particular accessibility both to the physical and the online world. The methods developed in this study might be used and extended to include accessibility to OHDS metrics to existing accessibility metrics that are used by policy makers.

Previously highlighted by (Lucas, 2012), lack of social equity in transport accessibility is partly driven by values, processes and actions of delivery agencies. Currently the delivery agencies of OHDS are private companies that have been following the developments in e-commerce markets during usual times. Covid-19 pandemic shows that the current service provision in this setting fails to address disadvantaged population segments which strongly encourages new values and new delivery agencies to step in for addressing this gap.

Although this research was conducted during the first wave of the pandemic (Spring 2020), a follow up data collection was collected during the third wave (Spring 2021) right before publication of this paper. For parcel deliveries there is no statistically significant change in the proximity to a pick-up point for Company#1 or in the density of pick-up points of Company#2. However, there is evidence that Company#1 is now coordinating with some suppliers to offer home deliveries to most postcodes in the VGR. Access to prescription drugs has changed significantly due to Pharmacy#2 now coordinating with Company#1 (i.e., the State-owned postal delivery company) to cover most postcodes with home deliveries of prescription drugs (99% compare to 62% during the first wave), data was not available for Pharmacy#1. Access to food also changed significantly with the indicator increasing from 0.38 to 0.61, this change is mainly driven by e-grocer #2 which offered home deliveries to 47% of postcodes during the second wave while during the third wave it offers home deliveries to 99% of them. Coverage of home delivery of meals has also increased from 7% to 18%. Further research after the pandemic should explore in detail the effect that the pandemic had on access to OHDS and whether the increase in access was temporarily or if it will continue helping to close the gap and reduce marginalization.

Acknowledgements

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Appendix. Number of cases for VGR

Municipality	Cases	Cases/10,000 inhab
Töreboda	178	192
Tibro	184	164
Boras	1318	116
Gothenburg	6722	116
Goth- Angered	816	150
Goth- Askim-Frölunda-Högsbo	642	100
Goth- Center	691	108
Goth- Lundby	654	119
Goth- Majorna-Linné	712	111
Goth- Norra Hisingen	599	116
Goth- Västra Göteborg	570	106
Goth- Västra Hisingen	531	93
Goth- Örgryte-Härlanda	776	127
Goth- East Gothenburg	731	141
Partille	448	114
Skovde	616	109
Tranemo	128	107
Lerum	453	106
Ulricehamn	252	102
Öckerö	131	101
Alingsås	409	99
Skara	182	97
Trollhattan	572	97
Mark	332	96

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Municipality	Cases	Cases/10,000 inhab
Tidaholm	123	96
Vårgårda	113	96
Mölndal	647	93
Härryda	347	91
Kungalv	372	80
Svenljunga	86	80
Ale	247	79
Vänersborg	314	79
Lidköping	304	76
Bollebygd	70	74
Mariestad	179	73
Uddevalla	406	72
Herrljunga	67	71
Grästorp	37	65
Lilla Edet	91	64
Bengtsfors	61	63
Sotenäs	56	62
Färgelanda	37	56
Amal	71	56
Essunga	31	55
Stenungsund	138	52
Vara	80	50
Lysekil	71	49
Falköping	159	48
Hjo	44	48
Munkedal	49	47
Tjorn	75	47
Mellerud	41	44
Gullspång	20	38
Orust	56	37
Karlsborg	25	36
Gotene	45	34
Tanum	43	33
Dals- Ed	14	29
Stromstad	29	22

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